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Gondo et al.

[54] **PRESS FORMING COLD ROLLED STEEL SHEET AND A PRODUCING METHOD THEREOF**

[75] Inventors: **Hisashi Gondo; Hiroshi Takechi; Mitsunobu Abe,** all of Kisarazu; **Norimasa Uehara; Kunihiko Komiya,** both of Kimitsu, all of Japan

[73] Assignee: **Nippon Steel Corporation,** Tokyo, Japan

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[52] **U.S. Cl.** .... **148/12 C;** 148/12.3

[51] **Int. Cl.**^{2} **C21D 9/48**

[58] **Field of Search** .... 148/12.1, 12.3, 12 C

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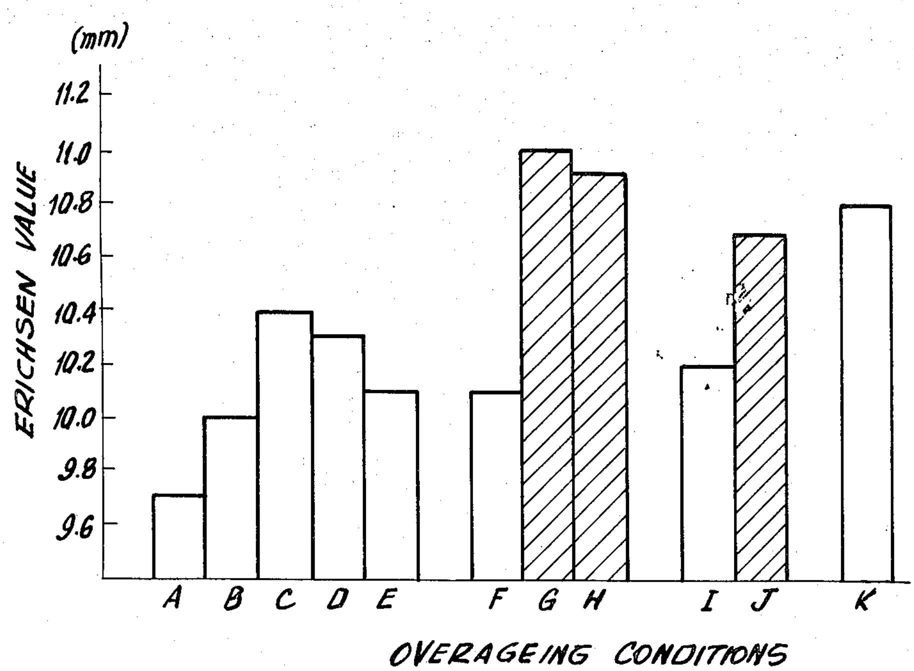
Primary Examiner—W. Stallard
Attorney, Agent, or Firm—Toren, McGeady & Stanger

[57] **ABSTRACT**

A cold rolled steel sheet having excellent press formability and ageing properties for auto bodies, especially improved stretchability and slow ageing properties, and a method for preparation thereof by means of a continuous annealing method.

1 Claim, 5 Drawing Figures



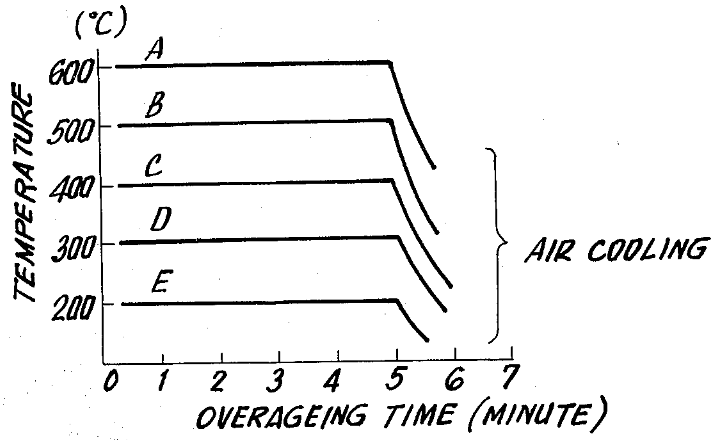


FIG. 1a

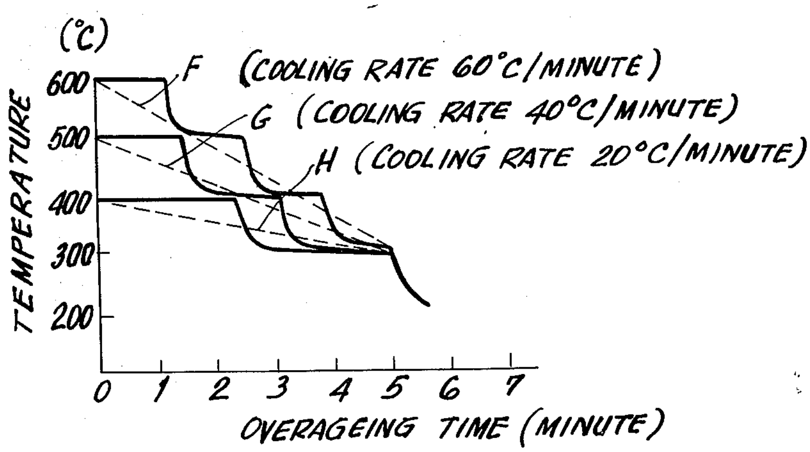


FIG. 1b

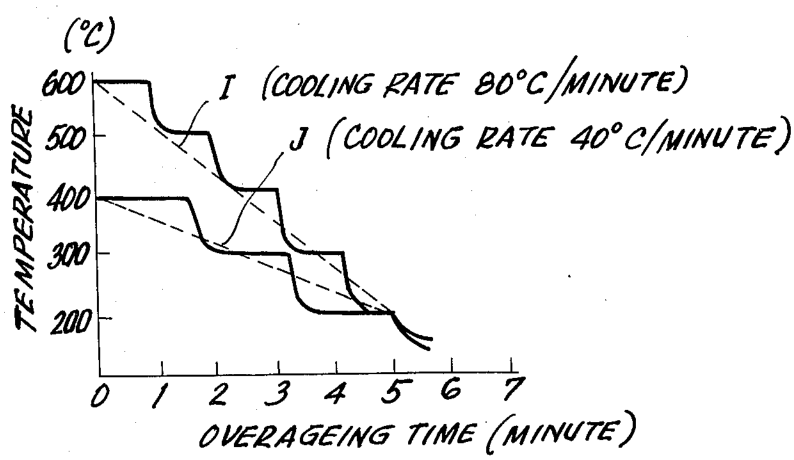


FIG. 1c

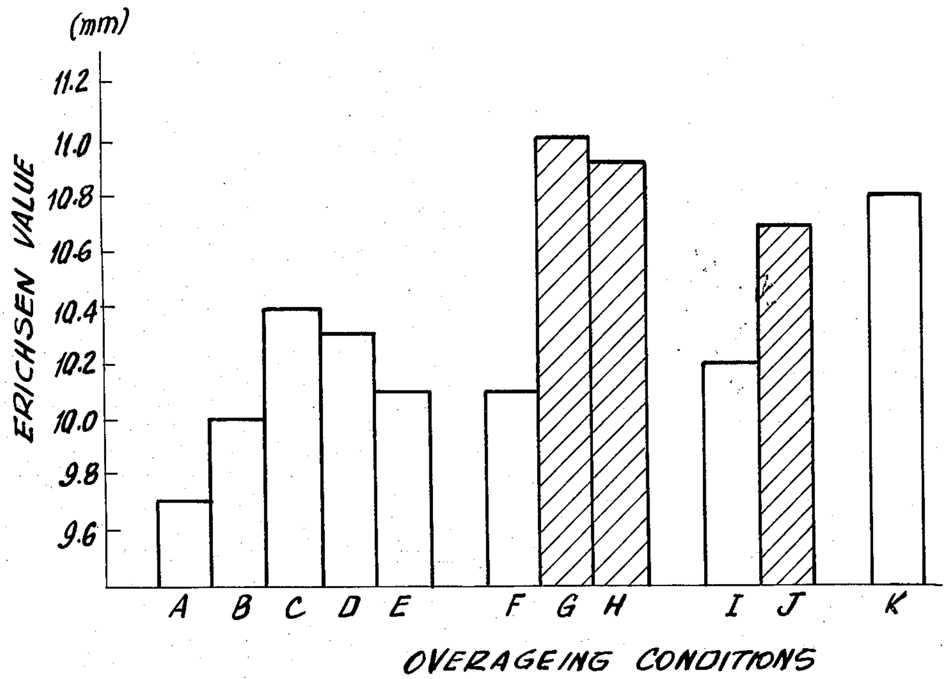

(mm)
ERICHSEN VALUE
11.2
11.0
10.8
10.6
10.4
10.2
10.0
9.8
9.6
A B C D E F G H I J K
OVERAGEING CONDITIONS

FIG. 2

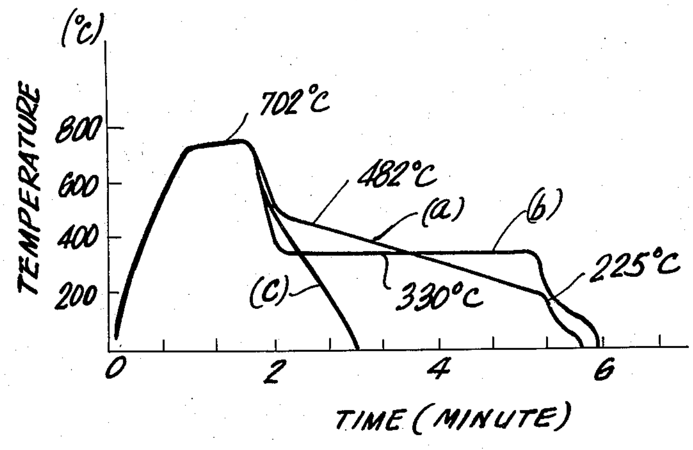

(°C)
TEMPERATURE
800
600
400
200
702°C
482°C
(a)
(b)
225°C
(c)
330°C
0 2 4 6
TIME (MINUTE)

FIG. 3

PRESS FORMING COLD ROLLED STEEL SHEET AND A PRODUCING METHOD THEREOF

The present invention relates to a cold rolled steel sheet having excellent press formability and a producing method thereof.

Conventionally, press forming cold rolled steel sheets for applications such as auto bodies have been required to have excellent deep drawability and stretchability and as well as good ageing property.

In the deep drawing operation, only a small force for preventing wrinkles is given to the steel sheet being press formed, and said sheet is formed from its outer portions into the dies by the punch being pressed thereon. Therefore, the most important property required for the press forming steel sheet is a high $\bar{r}$ value. On the other hand, in the stretching operation, the wrinkle preventive force is remarkably increased, and only a slight portion of the steel sheets are pressed into the dies and only portions contacting the punch are expanded and pressed. In this case, the most important characteristic is a high Erichsen value, and additionally it is desired that yield stress is low both for deep drawability and stretchability, and elongation is large.

Cold rolled steel sheets subjected to the press forming are generally annealed after the cold rolling, but the steel sheets as annealed have high yield point elongation so that when the sheets are press formed, stretcher strain is caused and the surface appearance is damaged. For this reason, the sheets after the annealing are subjected to a temper rolling to eliminate the yield point elongation.

Even in this case, however, if the sheet is left for a long time thereafter, before the subsequent press forming, the yield point elongation is restored due to the ageing of carbon and nitrogen in solid solution and thus the stretcher strain is again caused during the press forming.

The cold rolled steel sheet in which the yield point elongation is not restored even when the sheet is left for a long time after the temper rolling, are called non-ageing steel sheets and the steel sheets in which the restoration of the yield point elongation is slow, are called a slow ageing steel sheets. And the steel sheets for press forming have non-ageing, or at least a slow ageing property, deep drawability and stretchability.

Conventionally, the cold rolled non-ageing or slow ageing steel sheets having above mentioned properties for auto bodies have been commercially produced by applying a box annealing to Al-killed steel.

The Al-killed steel contains aluminium in such an amount as to be enough to form AlN during the heating of the annealing and is effective to improve the $\bar{r}$ value in the cource of the AlN formation, and fixes the solid solution nitrogen as AlN, thus improving the ageing property. However, in case of the Al-killed steel, pipes are formed during the ingot making in the head portion of the ingot, which cause inner defects in the final product, and thus it is necessary to cut off the head portions. As the Al-killed result, the production yield of the Al-killed steel is remarkably lowered. In addition, the box annealing requires normally more than 60 hours and thus is not desirable for the production efficiency. In spite of these disadvantages, the cold rolled steel sheets having good deep drawability, stretchability as well as good ageing property suitable for press forming of the auto bodies have been produced only by using the Al-killed steel of low production yield and applying the box annealing of low production efficiency.

Therefore, one of the object of the present invention is to provide a cold rolled steel sheet having an excellent press formability and ageing properties for auto bodies, especially improved stretchability and slow ageing properties.

Another object of the present invention is to provide a method for producing the cold rolled steel sheet having an excellent press formability and ageing property for auto bodies, especially improved stretchability and slow ageing property, by means of a continuous annealing method.

The purposes of the present invention are:

1. a cold rolled steel sheet for press forming having a chemical composition comprising not more than 0.1% carbon and not more than 0.30% manganese in which

$$0.002.N(\text{ppm}) - 0.03 \leq K \leq 0.17 + 0.002N(\text{ppm})$$

where,

$$K = Mn(\%) - \frac{55}{32}S(\%) - \frac{55}{16}O(\%)$$

2. a method for producing a press forming cold rolled steel sheet comprising not more than 0.1% C and not more than 0.30% Mn and satisfying the conditions

$$0.002 \times N\ \text{ppm} - 0.03 \leq K \leq 0.17 + 0.002 \times N\ \text{ppm}$$

where,

$$K = Mn - \frac{55}{32}S - \frac{55}{16}O$$

which comprising an ordinary hot rolling step, a cold rolling step and a continuous annealing step;

3. a method according to above (2), which further comprises an overageing step;

4. a method according to above (3), in which the annealing done at a temperature between the recrystallization temperature and 900°C for not longer than 5 minutes, and the overageing is done between 300° and 500°C for not longer than 10 minutes;

5. a method for producing cold rolled steel sheet having good press formability, comprising passing a cold rolled steel strip containing not more than 0.1% carbon through a continuous annealing furnace composed of a heating and a soaking zone, a primary cooling zone, an overageing zone, and a secondary cooling zone arranged in series, in which 30 seconds to 5 minutes heating and soaking is effected at a temperature between 650° and 900°C in the heating and soaking zone, cooling down to the starting temperature of overageing or below is effected in the primary cooling zone, and overageing with starting temperature between 400° and 500°C and then stepwisely or continuously lowering temperature between 200° and 500°C is effected for 2 to 10 minutes and the overageing is completed between 200° and 350°C; and

6. a method for producing a slow ageing cold rolled steel plate for press forming comprising hot rolling a steel slab having a chemical composition comprising not more than 0.1% carbon and not more than 0.30% manganese, in which

$$0.002.N(\text{ppm}) - 0.03 \leq K \leq 0.17 + 0.002.N(\text{ppm})$$

where,

$$K = Mn(\%) - \frac{55}{32}S(\%) - \frac{55}{16}O(\%)$$

coiling the hot rolled strip at a temperature between 600° and [850 − 2.1 × 10³ × C(%)]°C, cold rolling the hot rolled strip by a conventional method, and passing cold rolled strip thus obtained continuously through a continuous annealing furnace composed of a heating and soaking zone, a primary cooling zone, an overageing zone, and a secondary cooling zone arranged in series, in which 30 seconds to 5 minutes heating and soaking is effected at a temperature between 650° and [1680 − 4.6 × 10³ × C(%) − the hot coiling temperature (°C)] °C in the heating and soaking zone, cooling down to the starting temperature of overageing or below is effected in the primary cooling zone, and overageing with starting temperature between 400° and 500°C and then step-wisely or continuously the lowering temperature at the starting temperature of overageing between 200° and 500°C is effected for 2 to 10 minutes in the overageing zone, the overageing is completed between 200° and 350°C.

The present invention will be described in detail referring to the attached drawings.

FIG. 1 *a*, *b* and *c* respectively show a graph of heat cycles of isothermal overageing and stepwise overageing.

FIG. 2 is a graph showing Erichsen values of steel materials subjected to isothermal overageing and stepwise overageing.

FIG. 3 is a graph showing a heat cycle in the continuous annealing furnace.

In general, metal materials having a larger grain size are softer and more suitable for cold working and show larger Erichsen values, elongation, and $\bar{r}$ values and lower yield stress with good ageing properties. The size of the grains depend on the chemical composition and the heating history in the production process.

Mn, S and O are elements which harden the steel and lower deep drawability and stretchability by their solid solution hardening effects or by grain refinement due to their recrystallization preventing effects or by both. However, if Mn combines with S and O to form MnS and MnO, the grain refinement-tendency due to the solid solution hardening and the recrystallization preventing effects disappear and large grains are obtained, thus improving deep drawability and stretchability. In this case, however, if Mn or any or both of S and O remains excessively in a large amount, they are harmful. In case the coefficient K is established as under

$$K = Mn(\%) - \frac{\text{Atomic weight of } Mn}{\text{Atomic weight of } S} \times S(\%) - \frac{\text{Atomic weight of } Mn}{\text{Atomic weight of } O} \times O(\%) = Mn(\%) - \frac{55}{32}S(\%) - \frac{55}{16}O(\%)$$

if K is remarkably smaller than zero, this means that either or both of S and O is excessive in a large amount, and if K is remarkably larger than zero, this means that Mn is excessive in a large amount.

Therefore, deep drawability and stretchability can be improved by setting the K value in a certain range. As mentioned above, the large excessive amount of Mn is harmfull, but a small excessive amount of Mn is very effective to improve the ageing property. If MnS and MnO are present in a large amount, they by themselves cause fractures during the press forming operation, and it is necessary to maintain MnS and MnO as low as possible. Regarding the carbon content, more than 0.1% carbon causes material hardening, and thus the carbon content should be not more than 0.1%.

For the reasons set above, the chemical composition of the slow ageing cold rolled steel sheet for press forming according to the present invention is limited so as to satisfy the following conditions.

Carbon ≤ 0.1%

Manganese ≤ 0.30%, preferably ≤ 0.25%

$$K = Mn(\%) - \frac{55}{32}S(\%) - \frac{55}{16}O(\%) \quad \text{and}$$

0.002.N (ppm) − 0.03 ≤ K ≤ 0.12 + 0.002.N (ppm)

In this case, a low level of N content is preferable, especially N content less than 25 ppm improves some mechanical properties such as drawability and ageing property.

By balancing the four components, Mn, S, O and N appropriately according to the present invention, or additionally by restricting the upper and the lower limits of the hot coiling temperature, it is possible to produce a cold rolled steel plate suitable for press forming of the auto bodies and comparable with steel sheet produced by box annealing method.

Next, the second purpose of the present invention will be described hereinunder.

The cold rolled steel sheet to which the method of the present invention is directed, may be produced from any of a rimmed steel, a capped steel, a killed steel and other steels containing various alloying elements and impurities, so far as the carbon content is not more than 0.1% and the desired results of the present invention can be obtained.

The feature of the present invention lies in the uses of the continuous annealing method as specified.

According to the box annealing method, steel coils or cut sheets are heated for soaking and then cooled in a piled condition and the heat capacity of the piled steel coils or cut plates is so large that it takes about 10 hours to heat the whole of the piled coils or cut plates to a predetermined annealing temperature, and the cooling after the soaking is very slow and it usually takes more than one day to cool the coil or the plate to a room temperature from the soaking temperature.

Whereas, according to the continuous annealing method of the present invention, the steel strip is once uncoiled into a strand form and supplied to an annealing furnace so that the heat capacity of the material to be annealed is so small that it is possible to heat the material to the soaking temperature in a short time, that is recrystallization can be completed by 30 seconds to 5 minutes soaking at a temperature between a recrystallization temperature and 900°C, with similar results as in the box annealing method. When the soaking temperature is lower than recrystallization temperature or the soaking time is shorter than 30 seconds, the recrystallization is not enough, while when the soaking temperature is higher than 900°C and the soaking time is longer than 5 minutes, no substantial improvement of the material is obtained with only lowering of the production efficiency and also $\bar{r}$ value remarkably decreases.

As the cooling rate after the soaking is very slow in the box annealing, the carbon atoms in solid solution present at the beginning of the cooling gradually precipitate as carbides during the cooling in correspondence to the change in the solid solution limit of carbon in the equilibrium diagram, and the amount of the solid solution carbon becomes smaller until the solid solution hardening effect by carbon disappears thus improving the stretchability and the ageing property of the material.

According to the continuous annealing, as the heat capacity of the material passing through the heating and soaking zone of the furnace is so small that the material is rapidly cooled down to the room temperature within 10 minutes. Therefore, a considerable part of the solid solution carbon which was present in the material at the beginning of the cooling is retained in the solid solution and thus the stretchability and the ageing property of the material are deteriorated by the solid solution hardening. In order to prevent the problem, the material is cooled down to the overageing temperature or below and then the material is subjected to an overageing treatment at a temperature below the soaking temperature to precipitate the excessive solid solution carbon as carbides.

When the overageing temperature is high, the diffusion rate of the carbon is rapid and thus the carbide precipitation is completed in a short time, but the solid solution limit of carbon is so high that the amount of the residual solid solution carbon is large. Therefore, the overageing is not complete. On the other hand, when the overageing temperature is low, the diffusion rate of carbon is so slow that a long time is required for the completion of the carbide precipitation, but the solid solution limit of carbon is so small that the amount of the residual solid solution carbon is very small and thus the overageing is complete. In this way the selection of the overageing temperature has an alternative significance that it increases the production effeciency or assures the complete material quality such as stretchability. In the conventional art, either of the advantages has been sacrificed.

According to the present invention, the material is cooled from the soaking temperature to the starting temperature of the overageing or below, and overageing with starting temperature between 400° and 500°C is effected for 2 to 10 minutes with the temperature stepwisely or continuously lowering between 200° and 500°C and the overageing is completed between 200° and 350°C, thereby the advantages that the carbide precipitation is completed rapidly by a high temperature overageing and that the residual solid solution carbon is remarkably reduced by a low temperature overageing are assured while the defects of the high and low temperature overageing are eliminated, thus maintaining the stretchability, preventing the ageing due to the solid solution carbon, and improving the productivity.

For the practice of the present invention, it is desirable that the cooling from the soaking temperature to a temperature below the starting temperature of the overageing is conducted at a rate of 5° to 30°C/second. Even during the cooling from the soaking temperature, the diffusion rate of the carbon is remarkably high immediately below the soaking temperature, it is not desirable that the cooling rate in the primary cooling zone exceedes 30°C/second in order to utilize also the carbide precipitate in this stage. Also with a cooling rate more than 30°C/second, the over saturation degree of carbon at the beginning of the overageing is high and the nuclei of the precipitating carbides become fine and increase in their number so that the overageing is promoted, as a result, there is large tendency of precipitation hardening which lowers the stretchability. While, even with a cooling rate below 5°C/second, any special advantage is not obtained, and the productivity is lowered. The cooling rate of 5° to 30°C/second from the soaking temperature to a temperature below the overageing temperature is a preferable range and not an essential range. The desired results of the present invention can be obtained even when the cooling rate is outside the above range.

When the starting temperature of the overageing is higher than 500°C, the solid solution of carbon becomes relatively large and the overageing is meaningless. At the beginning of the overageing between 400° and 500°C, carbides are formed at the grain boundaries when the above primary cooling rate is applied. For example, in case of the material containing 0.02% carbon, the solid solution limit at 700° and 400°C is respectively 0.02% and 0.0036% and thus most of the solid solution carbon precipitates as grain boundary carbides at this stage, but a small amount of solid solution carbide remains. The residual solid solution carbon even in such a small amount is harmfull to the stretchability and the ageing property. Just before the finishing of the overageing between 200° and 350°C, the residual solid solution carbon precipitates as fine carbides in the grains and the residual solid solution carbon is reduced to a negligible amount, for example to about 0.004% which is a solubility limit for carbon at 300°C.

The presence of the small amount of the above fine carbide in the grain is useful for delaying the ageing without damaging the stretchability and this can not be expected in the box annealing and one of the features of the present invention. When all of the solid solution carbon which was present at the time of the soaking precipitates as the fine carbide in the grains, the precipitation hardening as mentioned before is caused and thus the stretchability is deteriorated, although advantageous for the slow ageing.

According to the present invention, 2 to 10 minutes are given from the beginning of the overageing (400° to 500°C) to the completion of the overageing (200° to 350°C) during which the overageing temperature is lowered stepwisely or continuously. With less than 2 minutes of overageing, the object of the overageing is not attained, while with more than 10 minutes of overageing, the advantage of the continuous annealing in the improved productivity is not attained. The most desired conditions of the overageing are: the beginning of the overageing between 400° and 450°C, the completion of the same between 250° and 300°C, and the total period of the overageing of 3 to 6 minutes.

The overageing with the continuously lowering temperature used herein means the case where the temperature lowering rate at each position in the overageing zone is within ±30% of the average temperature lowering rate obtained by dividing the difference between the beginning temperature and the completing temperature of the overageing by the total overageing time. And the overageing with the stepwisely lowering temperatures and used herein means as under. The overageing zone is divided into two or more isothermal overageing zones, where the overageing temperature stepwisely lowers, each of the isothermal times is maintained within ± 30% of the average isothermal overageing time obtained by equally dividing the total passing time in the total isothermal zones by the number of the isothermal overageing zones and the temperature range in each of the isothermal overageings is maintained within ± 30% of the average overageing temperature difference obtained by dividing the difference between the beginning temperature and the completing temperature of the overageing by the number of the isothermal overageing zones and the transition zone between the isothermal overageing zones is passed through in time shorter than 50% of average isothermal overageing time.

When the above overageing conditions are not applied, and only the isothermal overageing between 400° and 500°C is applied, a harmful amount of residual solid solution carbon for the stretchability and the ageing properties will remain even if the long isothermal overageing may be applied, because the solid solution limit of carbon in the above temperature range is high, and when only the isothermal overageing between 200° and 350°C is applied, the precipitation of solid solution carbon is so slow that a long time is required by the overageing, thus no practical value is assured. And particularly, application of only the isothermal overageing between 200° and 300°C is not desirable because a large amount of solid solution carbon is converted into fine carbides in the grains and the stretchability is deteriorated by the precipitation hardening. Overageing conditions mentioned above are preferable operation.

In the secondary cooling zone, it is desirable to cool the material down to near the room temperature as rapid as possible for improvement of the production efficiency.

As described above, it has been made possible by the present invention to produce by a continuous annealing method, a cold rolled steel sheet having stretchability comparable to that obtained by the box annealing at high production efficiency, and the commercial advantages of the present invention are very remarkable.

Next, the purpose of the present invention will be described hereinbelow.

The slow ageing cold rolled steel sheets for press forming according to a purpose of the present invention will have more desirable properties by applying the continuous annealing method as described hereinbefore. In this case, however, the hot coiling temperature is important.

First, a hot rolled steel strip is prepared from a rimmed capped or killed steel having the following chemical compositions;

C ≤ 0.1%

Mn ≤ 0.30% preferably ≤ 0.25%

0.002.N (ppm) − 0.03 ≤ K ≤ 0.17 + 0.002.N (ppm)

$$K = Mn(\%) - \frac{55}{32} S(\%) - \frac{55}{16} O(\%)$$

For the production of the above hot rolled steel strip, the hot coiling temperature is limited as under in order to promote the reactions of Mn + S → MnS and Mn + O → MnO for the reasons mentioned hereinbefore. When the strip is coiled after the hot rolling, the cooling rate after the hot rolling is very slow, so that the strip is maintained at the high temperature for a long time, and particularly when the coiling is done at a temperature not lower than 600°C, more preferably not lower than 650°C, the formation of MnS and MnO by the above reaction is remarkably promoted. On the other hand when the coiling temperature is too high, coarse carbides are formed, which promote the fracture during the press forming. Thus the upper limit of the coiling temperature is limited to [850 − 2.1 × 10^3 × C(%)]°C.

The hot rolled steel strip thus obtained is cold rolled and then continuously annealed by passing the strip through the continuous annealing furnace in which a heating and soaking zone, a primary cooling zone, an overageing zone and a secondary cooling zone, are arranged in series.

In order to obtain satisfactorily large grain size in the heating and soaking zone, soaking of not shorter than 30 seconds at a temperature nor lower than recrystallization temperature is required. On the other hand, even if the soaking is conducted for a longer time than 5 minutes no special advantage is obtained for the enlargement of the grains, but the longer time of the soaking only lowers the production efficiency. Thus the soaking time should be limited to not more than 5 minutes, when the annealing temperature is too high, coarse carbides are formed, which promote the fracture during press forming. Thus the upper limit of temperature should be determined in relation to the hot coiling temperature. In this way, the soaking condition of the present invention is limited as between 650°C and [1680 − 4.6 × 10^3 × C(%) − the hot coiling temperature (°C)]°C for 30 seconds to 5 minutes.

Further, the secondary cooling should be done as rapidly as possible to 40°C. This is desirable for the improvement of the production efficiency. The steel strip cooled down below 40°C which has been passed through the secondary cooling zone is, if necessary, subjected continuously 1.0 to 1.5% temper rolling to eliminate the yield point elongation and to prevent the stretcher strain and subjected to levelling for shape correction, and then coated with rust preventive oil or solid lubricating oil for the press forming, finally coiled for shipment.

The present invention will be more clear from the following examples.

EXAMPLE 1

A capped steel refined in a convertor and comprising 0.04% C, 0.23% Mn, 0.010% S, 0.011% P, 0.01% Si, 0.042% O and 15 ppm N, with the balance being iron and unavoidable impurities was made into slabs by an ordinary method. After soaking at 1200°C for 5 hours, the slab was hot rolled into 2.6 mm thickness with a finishing temperature of 890°C and coiled at 710°C. After acid pickling for scale removal, the hot rolled strip was cold rolled into 0.8 mm thickness and electrically cleaned, and subjected to a recrystallization annealing at 700°C for 2 minutes in a salt bath furnace. Then an isothermal overageing and a stepwise overageing as shown in FIG. 1 were conducted for 5 minutes of overageing using salt baths maintained at 600°, 500°, 400° and 300°C, an oil bath maintained at 200°C. The cooling rate from the annealing temperature to the starting temperature of the overageing was 10° to 15°C/second.

Erichsen values of the samples are shown in FIG. 2, and the samples G, H and J, which are within the scope of the present invention show particularly high Erichsen values, which are similar to that of the sample X which was box annealed for 4 hours at 700°C for comparison.

EXAMPLE 2

Three rimmed steel ingots refined in a convertor and comprising 0.04% C, 0.22% to 0.24% Mn, 0.01% Si, 0.008% to 0.012% S, 0.010 to 0.012% P, 0.032 to 0.041% 0, 9 to 12 ppm N, with the balance being iron and unavoidable impurities were processed in the same way as in Example 1 up to the cold rolling, passed through a vertical continuous annealing furnace provided with an electrical cleaning device in the front and a temper leveller and an oil coater in the rear, where annealing cycles (*a*), (*b*) and (*c*) shown in FIG. 3 were applied and 1.5% temper rolling was conducted. The properties of the products thus obtained are shown in Table 1 together with the properties of the product obtained by a box annealing of a coil of the above composition at 700°C for 4 hours and 1.5% temper rolling.

Table 1

Continuous Annealing Cycles and Material Properties Annealing Cycle	(a)	(b)	(c)	Box Annealing
Yield Stress (kg/mm²)	18.8	21.1	26.5	19.2
Tensile Strength (kg/mm²)	32.1	32.3	35.6	32.4
Fracture Elongation (%)	47.0	42.6	38.1	46.0
Erichsen Value (mm)	10.9	9.7	9.2	10.9
Hardness (HRB)	40	44	53	41

In case of the annealing cycle (a) according to the present invention, with only 3 minutes of overageing, products completely comparable with that of the box annealing was obtained.

EXAMPLE 3

Cold rolled steel strip of 0.8 mm thickness obtained from hot rolled steel strip of 2.6 mm thickness coiled at 680°C, having a chemical composition of 0.04% C, 0.015% Mn, 0.01% Si, 0% S, 0.013% P, 0.040% 0 and 15 ppm N with the balance being iron and unavoidable impurities was heated to 700°C in one minute and ten seconds, maintained at the temperature for one minute and subjected to the primary cooling to the starting temperature of overageing of 450°C with cooling rates of 10°C/second, 30°C/second, 60°C/second, and 100°C/second, maintained at 450°C for one minute, cooled from 450°C to 350°C in 25 seconds, subjected to overageing at 350°C for one minute and the secondary cooling to the room temperature in 2 minutes and 1.5% temper rolling.

The results of the tests of the mechanical properties of the samples are shown in Table 2, from which it is clear that in case of the primary cooling rates of 60°C/second and 100°C/second which are outside the present invention, the Erichsen value is low and the stretchability is also poor.

Table 2

Primary Cooling Rates (°C/second)	Primary Cooling Rates and Material Properties 10	30	60	100
Yield Stress (kg/mm²)	19.1	19.0	21.6	23.8
Tensile Strength (kg/mm²)	32.1	32.8	33.7	33.5
Fracture Elongation (%)	47.5	48.0	44.3	40.4
Erichsen Value (mm)	10.9	10.8	10.2	9.9
Hardness (HRB)	41	40	43	46

EXAMPLE 4

Capped steels No. 1 to No. 7 and Al-killed steel No. 8 refined in a convertor and having the chemical compositions shown in Table 3 were hot rolled with a finishing temperature between 890° and 900°C into hot rolled strips of 2.6 mm thickness, coiled at various coiling temperatures shown in Table 3, acid pickled, cold rolled into cold rolled strips of 0.8 mm thickness. The steels No. 1 to No. 6 were heated to 700°C in one minute and 10 seconds in the continuous annealing furnace, maintained at 700°C for one minute, cooled to the starting temperature of the overageing of 450°C with a cooling rate of 15°C/second, subjected to a stepwise overageing composed of three isothermal overageings of 450°C for one minute, 350°C for one minute and 250°C for one minute, with the transition times between the first and the second isothermal overageings and between the second and the third isothermal overageings being 20 seconds, cooled to the room temperature in one minutes and 20 seconds, and subjected to 1.3% temper rolling.

For comparison, the capped steel No. 7, and the Al-killed steel No. 8 were box annealed at 700°C for 4 hours and 16 hours respectively and were subjected to 1.5% temper rolling. The results of tests on the mechanical properties for these comparison samples are shown in Table 4. In the steels No. 1 and No. 2 treated according to the present invention, the yield stress, the elongation the *r* value and the Erichsen value are all on the same level to that of the box annealed Al-killed steel No. 8 and the press formability is better than that of the steel No. 8. Although the ageing property is somewhat lower than that of the Al-killed steel No. 8, the yield point elongation after the ageing is remarkably smaller as compared with the box annealed capped steel No. 7 and a slow ageing property is completely obtained.

Table 3

Steel No.	Chemical Compositions & Conditions for Hot Coiling Etc. Chemical Compositions (%) C	Si	Mn	S	P	O	N	Sol.Al
1	0.03	0.01	0.22	0.011	0.012	0.045	0.0012	—
2	0.04	0.01	0.19	0.011	0.011	0.038	0.0019	—
3	0.04	0.01	0.17	0.012	0.014	0.052	0.0021	—
4	0.04	0.01	0.37	0.013	0.013	0.039	0.0019	—
5	0.07	0.01	0.19	0.011	0.013	0.031	0.0017	—
6	0.04	0.01	0.22	0.011	0.010	0.045	0.0015	—
7	0.04	0.01	0.35	0.013	0.012	0.048	0.0014	—
8	0.05	0.01	0.31	0.012	0.013	0.005	0.0048	0.038

Hot Coiling tempe-

Table 3-continued

Steel No.	Chemical Compositions & Conditions for Hot Coiling Etc. Chemical Compositions (%) C	Si	Mn	S	P	O	N	Sol.Al
	K_1	K		K_2	rature (°C)	E	F	Remarks
	−0.018	0.046		0.182	710	787	832	Present Invention
	0.008	0.041		0.208	680	766	816	"
	0.012	−0.029		0.212	680	766	816	Outside Present Invention (too small K value)
	0.008	0.214		0.208	680	766	816	" (too large K value and Mn)
	0.004	0.065		0.204	750	703	608	" (too high coiling temperature)
		0.046		0.200	570	766	946	" (too low coiling temperature)
	0.000 −0.002	0.163		0.198	570	766	946	Comparison Box annealed Material
	—	—		—	550	745	900	"

$K_1 = 0.002 \times N\ (ppm) - 0.03$
$K_2 = 0.17 + 0.002 \times N\ (ppm)$

$$K = Mn(\%) - \frac{55}{32} S(\%) - \frac{55}{16} O(\%)$$

$E = 850 - 2.1 \times 10^3 \times C\ (\%)$
$F = 1680 - 4.6 \times 10^3 \times C\ (\%) -$
Hot Coiling Temperature (°C)

Table 4

Steel No.	Mechanical Properties Yield Stress (kg/mm^2)	Tensile Strength (kg/mm^2)	Elongation (%)	r	Erichsen Value (mm)	Yield Point Elongation (%) after 100°C × 1 hr. ageing
1	19.9	32.8	48	1.73	11.1	1.3
2	20.1	33.0	47	1.69	11.2	1.5
3	22.6	34.1	42	1.38	10.3	2.8
4	23.2	34.4	41	1.26	9.8	3.2
5	24.1	34.8	41	1.48	9.6	2.3
6	23.8	34.5	42	1.25	9.8	2.7
7	19.8	33.1	45	1.30	10.8	5.2
8	20.2	32.4	47	1.72	11.0	0.0

What is claimed is:

1. A method for producing a slow ageing cold rolled steel plate for press forming comprising hot rolling a steel slab having a chemical composition comprising not more than 0.1% carbon and not more than 0.30% manganese in which

$0.002.N\ (ppm) - 0.03 \leq K \leq 0.17 + 0.002.N(ppm)$

where,

$$K = Mn(\%) - \frac{55}{32} S(\%) - \frac{55}{16} O(\%),$$

coiling the hot rolled strip at a temperature between 600° and [$850 - 2.1 \times 10^3 \times C(\%)$] °C, cold rolling the hot rolled strip by a conventional method, and passing the cold rolled strip thus obtained continuously through a continuous annealing furnace composed of a heating and soaking zone, a primary cooling zone, an overageing zone, and a secondary cooling zone arranged in series, in which 30 seconds to 5 minutes heating and soaking is effected at a temperature between 650° and [$1680 - 4.6 \times 10^3 \times C(\%)$ − the hot coiling temperature (20 C)] °C in the heating and soaking zone, cooling down to the starting temperature of overageing or below is effected in the primary cooling zone, and overageing with a starting temperature between 400° and 500°C and then step-wisely or continuously lowering the temperature at the starting temperature of overageing between 200° and 500°C is effected for 2 to 10 minutes in the overageing zone, and the overageing is completed between 200° and 350°C.

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